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EP 0322314 A EP 0321981 A EP 0227404 A
US 4928175 A US 4887155 A

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(54) **Automatic carcass grading apparatus and method**

(57) Apparatus for grading carcasses after slaughter comprises a plurality of video cameras C1, C2 adapted to be positioned adjacent to a slaughter line R to expose an image of a carcass P on said slaughter line from a plurality of different viewpoints, signal processing means to derive from said images a plurality of parameters characteristic of said carcass, storage means to store a corresponding plurality of parameters derived from prior measurement of reference carcasses, comparator means to compare said plurality of parameters with said corresponding plurality of parameters to derive a further parameter indicative of the grade of said carcass and indicator means to provide an indication of the magnitude of said further parameter.

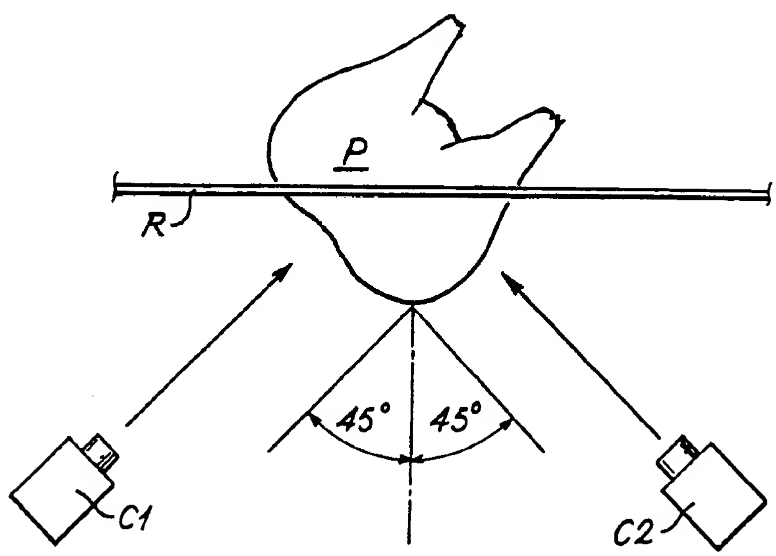

Fig. 7a

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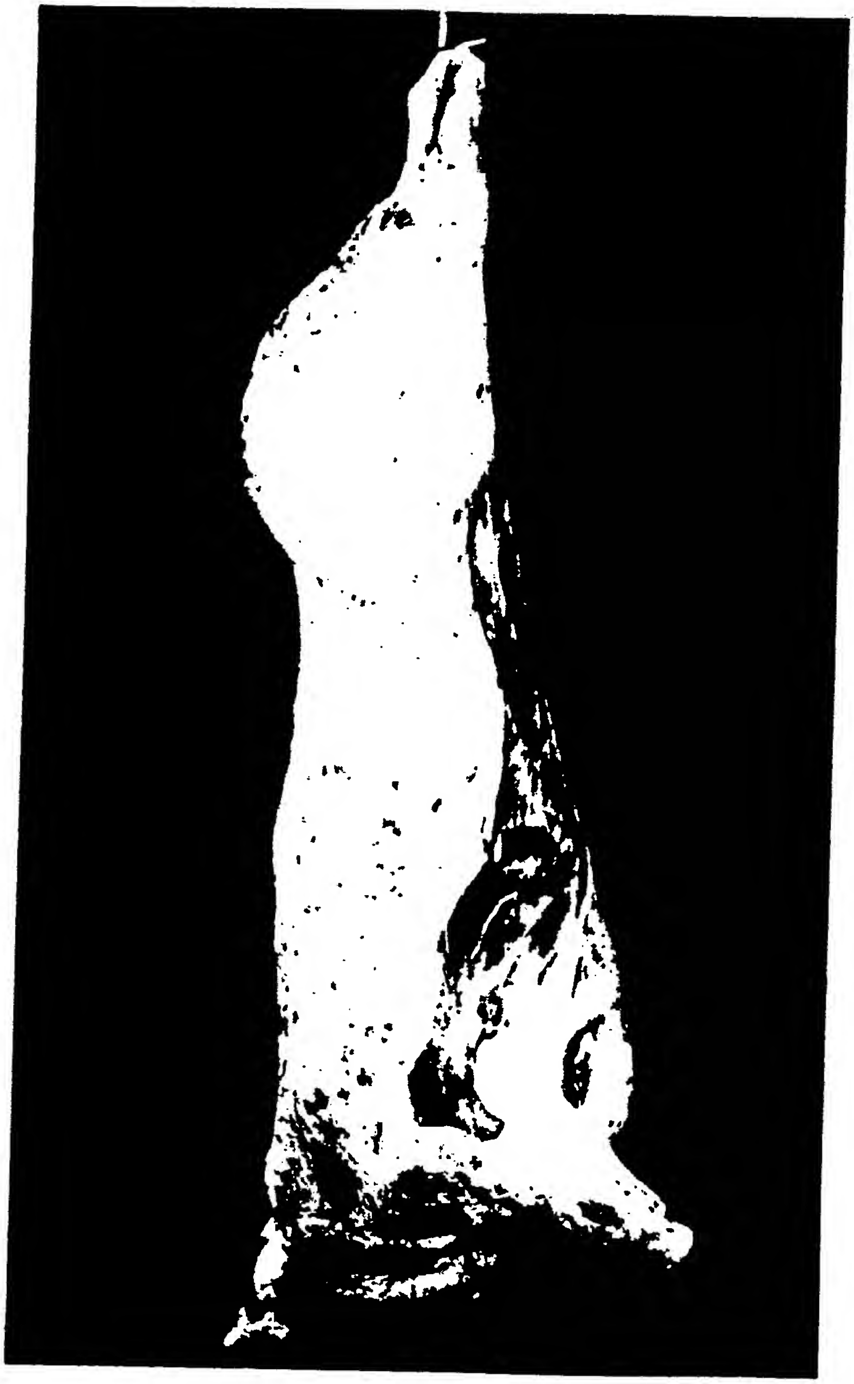

Fig. 1

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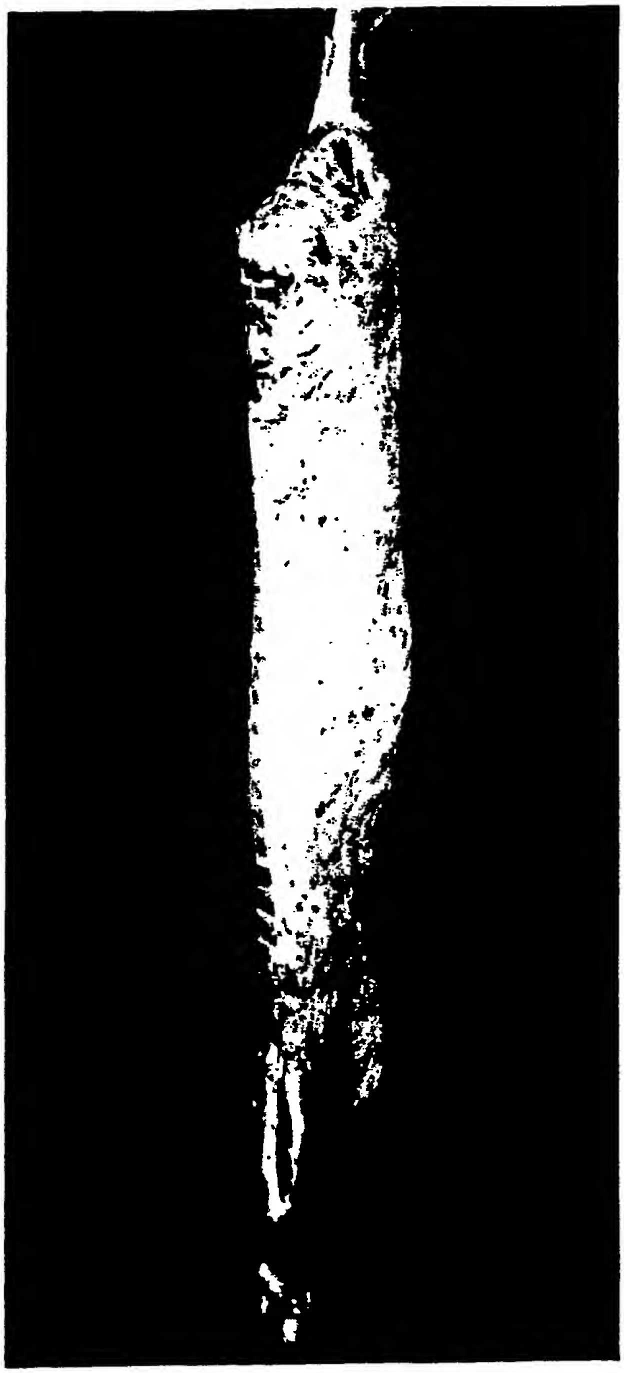

Fig. 2

Fig. 3

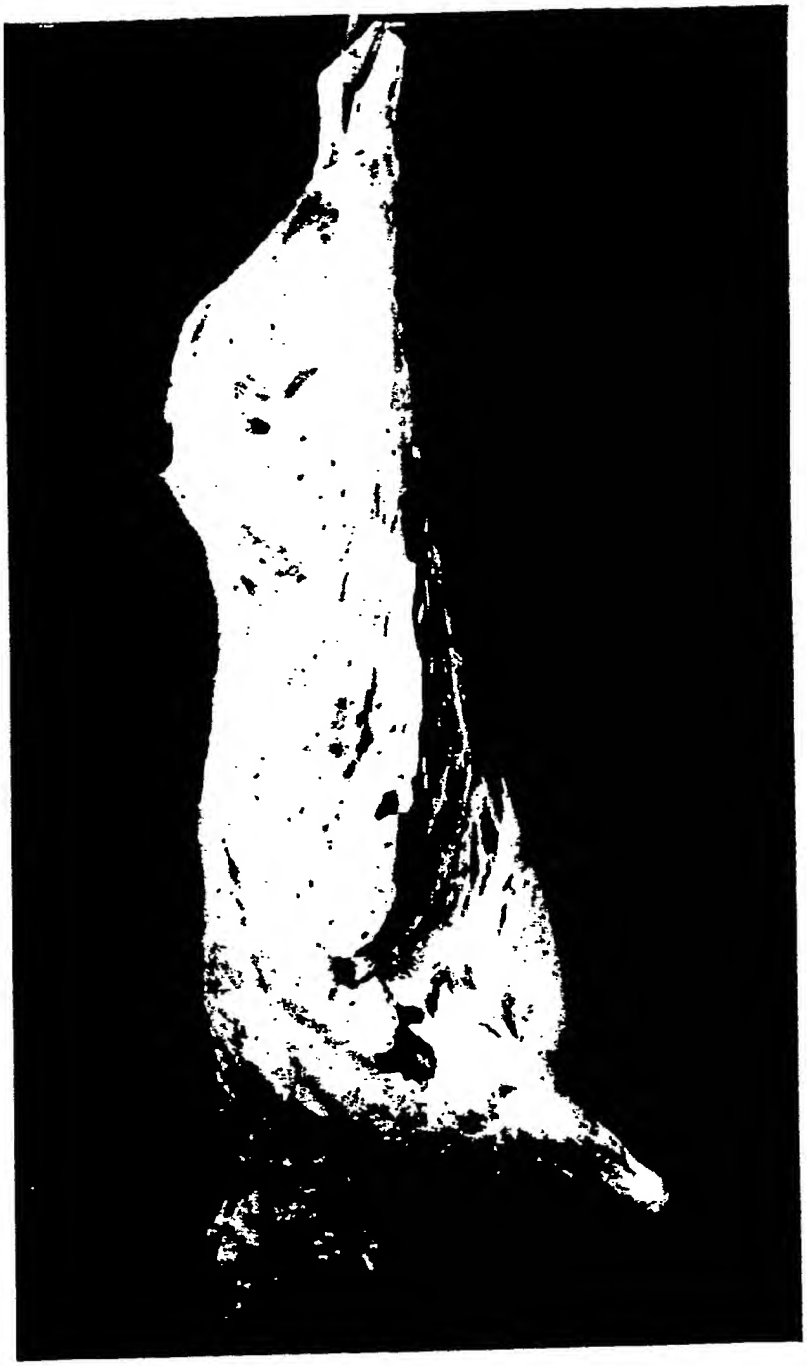

Fig. 4

Fig. 5

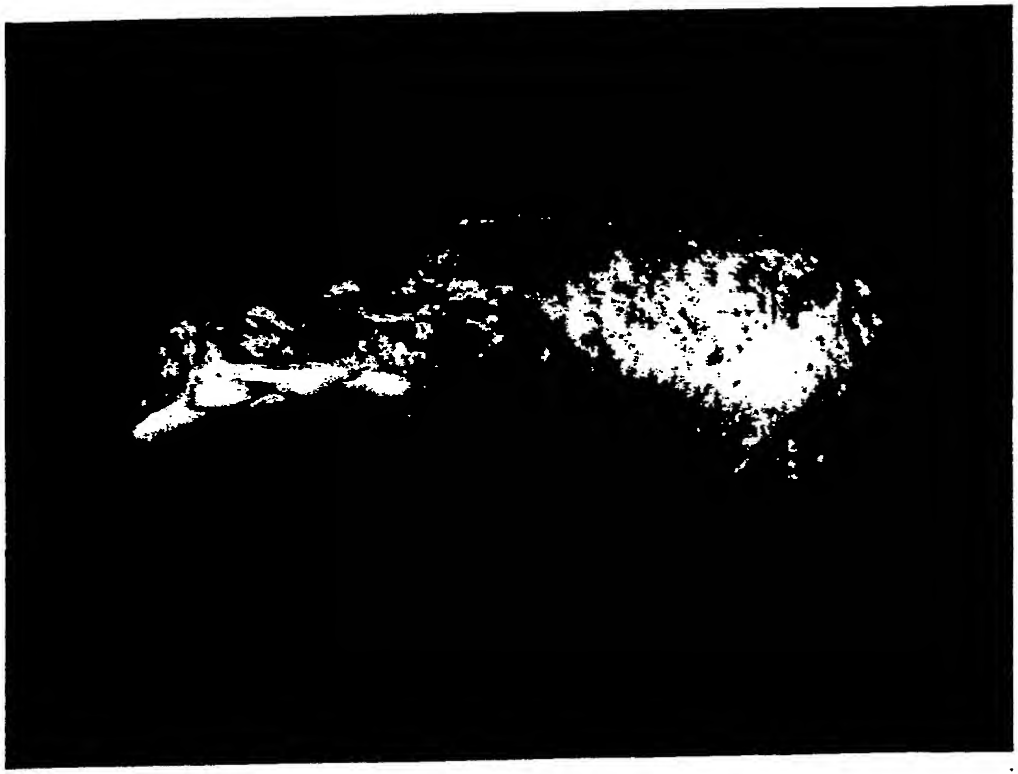

Fig. 6

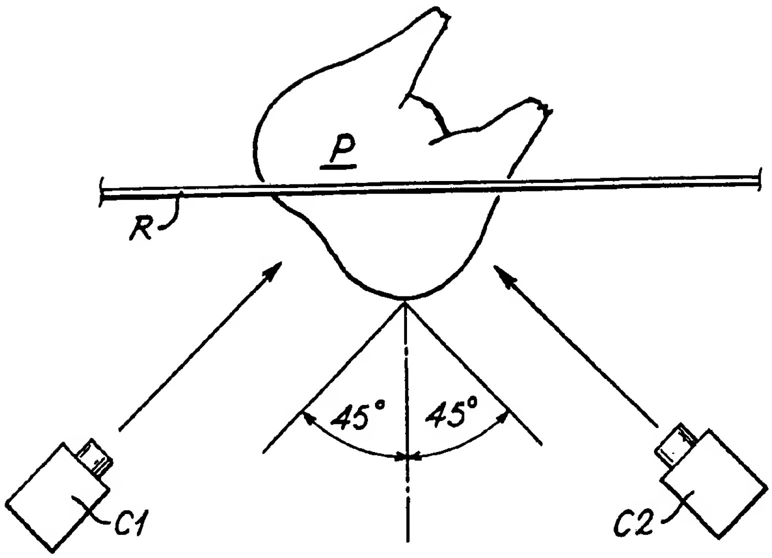

Fig. 7a

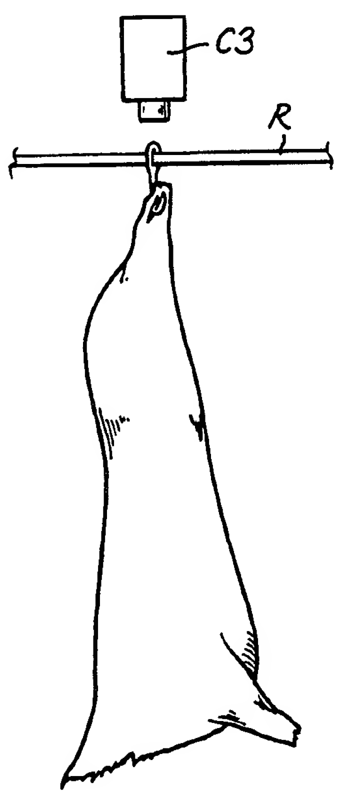

Fig. 7b

Automatic carcass grading apparatus and method

This invention relates to methods of and apparatus for the automatic grading of carcasses in abattoirs, processing plants and the like. Hitherto, grading of carcasses has been performed manually and thus has been subject to variations between and within operators. The assessments made from such a manual operation are totally subjective. In the case of beef carcasses there is an additional problem of perspective, the hind portion often being several metres away from and above the grader. With the intention of eliminating operator variability, an automatic inspection system using video cameras and image analysis has been devised.

Carcasses are graded according to officially accepted criteria, which vary from country to country. A transparent system has been devised on which it is possible to superimpose a variety of grading strategies. Examination of the total carcass as proposed in this method, gives information on specific sex, distribution and other attributes to which weighting factors (such as carcass weight and size) can be applied, if necessary, to determine an overall grade. Meat yield is calculated on the basis of normalised measurements, that is, by taking one or more views of the carcass and shrinking or expanding the image to a standard size and then comparing it with historic data from previous carcass measurements for which the meat yield and meat yield distribution has been determined. Initially this information may be less precise than required, but as the database on which such predictions are based expands, the precision of yield predictions and the accuracy of yield distribution will steadily improve. This enhancement may progress either in a passive manner by updates to the database or, in an active way, by means of an intelligent, dynamic database which continually expands through analysis of its acquired data.

Interpretation of the measurements has been based on an

in-depth observation of carcass dressing operations. For instance, there are three ways of taking the hide off an animal - totally manual, semi automatic or fully automatic. All of these operate in slightly different ways, with the manual technique being the most variable of the three. This means that the method of hide removal will determine how much the fat and thin muscles of the belly region (around the cutanus truncii) is actually ripped off. This, in turn, may indicate that the area around the belly is fat-reduced or even fat-free but it is a totally false indication because the fat has actually been removed. System intelligence has been developed to account for this and other aberrations that can be caused by dressing practice.

European Patent Application No.0321981A1 discloses a method and apparatus for determination of the conformation, fatness and other properties of individual cattle classes. The silhouette of a carcass or half carcass is recorded with a video camera in a special light screening chamber and a calculation of the parameters of the carcass made on the basis of an algorithm derived using a number of subjective assessments made by manual carcass graders. A second image may be recorded from the same viewpoint using different illumination.

One of the problems associated with this system is that it requires every carcass to go into a special viewing chamber. It needs a special loading and unloading facility and is therefore very limited in the number of carcasses that it can deal with. In particular, it is restricted to slow slaughter lines, and, in practice would not be usable for animals other than cattle. Furthermore, it requires modification of a slaughter line to enable it to be taken into use. It is restricted to measurements taken from a single viewing point, and therefore cannot cope with a widely varying population. It is apposite that the variability of beef carcasses in Denmark is very small indeed. It comprises almost a single line or a single cross and about 85% of it is young bull-beef, produced for the Italian

market.

According to the present invention there is provided a method of grading carcasses after slaughter comprising the steps of checking for the presence of a carcass in the field of view of a camera, checking that the orientation of said carcass with respect to the camera is in accordance with a predetermined arrangement, exposing an image of the carcass from a plurality of different viewpoints , determining a plurality of dimensions of said carcass from said images and comparing said dimensions with stored values to determine the overall grading of said carcass.

there is also provided apparatus for the grading carcasses after slaughter comprising a plurality of video cameras adapted to be positioned adjacent to a slaughter line to expose an image of a carcass on said slaughter line from a plurality of different viewpoints, signal processing means to derive from said images a plurality of parameters characteristic of said carcass, storage means to store a corresponding plurality of parameters derived from prior measurement of reference carcasses, comparator means to compare said plurality of parameters with said corresponding plurality of parameters to derive a further parameter indicative of the grade of said carcass and indicator means to provide an indication of the magnitude of said further parameter.

The invention will now be particularly described with reference to the accompanying drawings and photographs, in which:

Figure 1 is a lateral view of a well formed carcass, side

Figure 2 is a dorsal view of the same carcass half,

Figure 3 is the posterior/anterior view of the same carcass,

Figure 4 is a lateral view of a less well developed less well fleshed carcass,

Figure 5 the dorsal view of that same carcass,

Figure 6 is the posterior anterior view of that less well fleshed carcass and

Figures 7a and 7b are a schematic plan and side view of inspection apparatus set up in an abattoir.

Referring now to Figures 7a and 7b of the drawings, carcasses proceed along a rail R past a viewing position P. At the viewing position are three cameras C1,C2,C3 . One camera is positioned above the rail to provide a posterior/anterior view of the carcass. The other two are positioned laterally so that their lines of view are at 90° to one another and 45° to the rail. It is therefore possible to obtain lateral, dorsal and posterior/anterior views simultaneously. The same objective may be achieved by positioning the cameras at a 90° bend in the rail. In this case the cameras are again positioned above the rail and laterally at 90° to one another, but in this instance it is not necessary to orientate the carcass at 45° to the rail. A third option is to have the cameras staggered linearly. Such an arrangement would require the carcass to be rotated through 90° after leaving the lateral viewing position (C2) and before entering the dorsal viewing position (C3). The posterior/anterior camera (C1) can be suitably positioned above the dorsal viewing position.

It would be possible with the second arrangement, to eliminate one lateral camera if it were positioned at the bend, but care would have to be taken to ensure that images of other carcasses do not enter the field of view. In order to maintain line speed, it may be prudent to introduce a preview camera C4. This will enable the system to ensure that the carcass is correctly aligned and orientated prior to entering the grading station. If not, suitable remedial action to reposition the carcass can be taken without affecting the the continuity of the automatic grading operation.

With all animals, carcasses or split sides are supported by means of suspension from a hook or hooks running above a fixed rail. Within any one factory, the design of that hook will be specific as their rail will only accept one type of hook, the system being able to compensate for all variations in hook

length.

The carcasses are viewed when in a (1) warm, (2) semi-warm or (3) cold state; the preferred states being (2) or (3) which occur some thirty minutes onwards after slaughter. Prior to that the bulk of the fat is translucent and any fat cover and distribution information must be interpreted in a completely different way because as the fat becomes cold it becomes more reflective and less absorbent to light, this providing greater accuracy on relative thickness data.

The temperature is not usually measured because the conditions within the slaughterhouse and the cooling rooms are generally fairly well controlled. Each system will be calibrated to a defined set of environmental characteristics specific to that plant or abattoir. If conditions change radically, a new set of parameters will have to be installed.

Other information utilised in the grade calculations but not provided directly by the system are cold carcass weight or dressed carcass weight, that is when the hide and innards are removed and any miscellaneous pieces of fat such as channel fat and kidney knob fat are taken out. Such data are readily available in most establishments via an automatic weighing system.

As the carcass progresses through the system, it is first correctly orientated with respect to the predetermined position of the cameras. If the orientation is not correct, but line speed and operation maintained, then computer transformations and re-drawing would have to take place. This would require a lot of computing power and take a considerable time. Such a technique is possible on a beef grading line due to slower line speeds. With present technology, it is impractical for pig, lamb and all white meat lines.

The sequence is predetermined by the way the views are to be interpreted. Preferably, three views are taken, although two of these can actually be generated from the data of the other five. Provision has been made for another camera (C5) to

provide data on the content and distribution of fat overlying the ribs inside the dressed body cavity from a medial carcass view. Data provided from such a view will only be required if fat distribution data provided by the other defined camera positions is unclear, ambiguous or insufficient for grading to be accomplished. It is possible to magnify and zoom in on a particular image. Although the saving in equipment costs is marginal, it does reduce the processing time, which on fast line throughputs can be a significant advantage, although it may be accompanied by a marginal decrease in accuracy of yield prediction.

Three general views of the carcass are taken to provide basic data on overall carcass characteristics such as length, extent of minimum and maximum width, area distribution curves, etc. Each of the views are taken with a standard, non-interlaced high definition scan rate of 1/50th second, up to 800 lines, although faster shutter speeds can be accommodated if necessary. For most applications alternate line sampling is sufficient and permits the picture information to be processed much faster.

Three overall views provide the general carcass information. The information in these views is then processed by hardware, with a range of separation capabilities such as a differentiating circuit as an edge detector, or by dynamic software that shifts thresholds according to the type of carcass being viewed.

With certain species of animal, useful information can be obtained from an interior view of the carcass. However, due to size variations, it is advantageous to have a dynamic viewing window, the size of which is set in accordance with the dimensions of the carcass which have been determined previously.

Very thick fat exhibits a high reflectance value. With sheep in particular there are some problems with the translucent nature of the fat. With normal direct lighting, because at specific carcass locations there is a film of tissue, and as

there is structure underneath it, although one is on top of the other, it acts on occasions like a mirror, particularly when the carcass is still warm. When it is at a particular angle it bends the light causing it to reflect along this collagenous material, giving rise to reduced contrast. The problem can be overcome by using diffuse or indirect light.

In making yield predictions, it is important to determine the sex of the animal, because a heifer of identical conformation and weight to a steer will have more saleable meat on it than the steer just because the bone structure is lighter. Neck muscle is very pronounced and developed in a bull; the fat around udder region is smooth in cows and heifers but rough in bulls and steers. This and other distinguishing sex characteristics are determined by this system.

Image processing for carcass evaluation is a computer-intensive operation because the outline curves involved are complex spline curves, that is, they are composite curves made up of a large number of elementary components. The angularity, degree of curvature, length and other mathematical and geometric descriptions at a specific point or region on the carcass can be used objectively to define a shape at that point for comparison in the grading procedure and quantitatively to predict muscularity and thus lean meat yield.

Image analysis may be used in conjunction with other techniques and devices such as multiple wavelength infra-red measurement to measure or predict moisture content and also to predict the chemical liquid content.

When the carcass is fresh, the water content can be predicted with some accuracy; with butchered meat, however, the water status needs to be determined. Certain surface cuts of meat will lose water rapidly and interior cuts will lose water very slowly. The water content will effect the apparent lipid content. With on-line production techniques, the ability to measure fat and water content will enable accurate predictions of lean content to be made. This is necessary, for example, in

the manufacture of a calorie-controlled product.

With pig grading it is possible to obtain information on fat depth much more easily with other technologies rather than by image analysis. There are practical difficulties in looking at the cut surface of a pig, arising from factors such as blood splatter and fat smear. However, electrical resistance and reflectance probes are unable to measure changes in conformation and therefore tend to underestimate the lean content of well conformed animals and over-estimate saleable meat yield in carcasses of poorer conformation. Also, because their pigs are much more variable, European prediction equations are not suitable for the American pig population. In such applications, the use of image analysis to predict shape and muscularity, together with other technologies for fat depth information, will provide more accurate predictions of percentage yield. For beef, image analysis is well developed as a standalone technique. For sheep, because there are different fat distributions, particularly inter-muscular fat, other techniques, such as ultrasound scanning can provide valuable supplementary information for both grading and yield prediction.

With poultry, fat content and distribution around the hind quarters of the animal, particularly the cloacal region or around the neck fat are good indicators. These display themselves as changes in the carcass conformation. Therefore, with appropriate adaptation the techniques described above can be utilised to grade poultry carcasses with or without the addition of techniques to quantify fat content at the positions defined.

There are a number of objectives with this image analysis system. These include the ability to grade carcasses, which is important for producer payment, and predict yield, not solely for the total carcass but for some specific parts, such as the primals. The whole system not only has an attraction to the abattoir producer or the legislature, but it becomes a large marketing tool for meat purchasers such as the major

supermarkets, who at present determine, from data at point of sale, the quantity and type of meat being sold, but can only subjectively determine wholesale meat purchases. This technique will enable them to make bulk meat purchases based on accurate assessments of saleable meat. In addition, carcasses may be bought on a quantitative prediction of hindquarter to forequarter meat distribution.

In order to achieve an accurate prediction of primal yield, a cutting grid based on primitive measurements of length and width may be drawn and superimposed on each of the basic two-dimensional views. Since butchering methods vary from country to country, the advantage of this system is a new cutting grid can be superimposed to mirror the changes in butchery techniques.

The video cameras are specially constructed to achieve a predetermined spectral response. This may be modified, according to the specific circumstances, by use of filters, structured lighting, or by selection of a charge-coupled image sensing device with the desired response. In some instances it is not desirable to have filters in front of the cameras because it degrades the quality of the image. The spectral response is chosen to increase and enhance the separation between the colour of the components of the meat, particularly the fatness. For example, in applications where the meat may be different shades of red, purple or pink or the fat may be different shades of white or yellow, selection of the green output (from an imaging device with separate RGB output) gives the best separation for the lean meat colour in beef. Any one of the other RGB outputs may be used for the fat because the fat is reflecting across the whole spectral wavelength range. Alternatively, for certain applications data can be taken from each of the RGB outputs and a polygonal database can be built up together with or in addition to luminance/chrominance data on the way in which the colours are changing relative to compositional variations in component materials or alterations in physical or chemical

parameters during production. This is valuable for process control operations. Particular products can be examined a specific points in its process and from a database knowledge of the components at those points may be interpreted to show that there is, for example, too much fat in the product, or too much liquor, the pastry is not the correct consistency and so on. This information may be transmitted backwards and forwards down a process line to modify the product in accordance with an ideal market requirement. For most applications, however, it is sufficient just to keep to luminance, grey scale, or composite video information.

Because the efficiency of the system is influenced by a number of parameters including the luminance of the lights, the reflectivity of each carcass, electronic drift in the cameras or the system hardware, it is necessary for the system to be dynamically self-calibrating on system startup and self-compensating during operation. Self-compensation during operation is achieved by a combination of camera auto-iris, signal auto-gain and dynamic modification to system parameters via the system software.

The system described herein is also capable of self-diagnostics by means of which it is continually monitoring the performance of both the hardware and the software and will visually and audibly warn the operator of failures/errors and their degree of severity.

With such a proliferation of shape and tissue distribution information available from a number of two-dimensional views, such a system is capable of generating three-dimensional projections for individual carcasses. Using a process of normalisation it is thus possible to create and modify cutting pathways for robotic and automated systems from known and defined shapes present in the database based on the measurements quantified by the image analysis system. A similar approach can also be applied to carcass dressing procedures.

By the inclusion of an intelligent knowledge-based database,

the system described above is capable of objective meat inspection and other allied tasks.

In summary, image analysis is used to compile carcass data based on historic experience of what factors contribute to yield. A multiple thresholding technique enables fat distribution and content to be derived. Complex shape information can be stored as simple elements of spline curves. Other useful data, including carcass weight and specimen sex, can be used to bias the data as necessary. For particular curves and shapes tolerance databases can be set up. This shape information will be a mixture of area measurement, connectivity analysis, length, widths, boundary points and edge detection. Predetermined divisions can be set for each of these measurements and a bias introduced to those measurements to enable accurate grade and precise yield information to be generated. In conjunction with other information, accurate grading and yield prediction can be made for the three major red meat species. With some modification this can be extended to poultry.

This system also provides the basis for rapid automation of butchery and dressing techniques to be developed. The addition of artificial intelligence extends system use into areas of carcass welfare such as meat inspection.

A flow diagram for a preferred method of carcass grading is shown in Table 1.

Table 1

1. Check calibration
2. Carcass present/absent
3. Check carcass orientation
4. Measure overall dimensions for each view (fat areas/bulk)
5. Re-scale grid and superimpose
6. Obtain area data with different thresholds within each cell (area)
7. Obtain shape conformation/information within each cell (edge connectivity)
8. Determine sex characteristic if necessary
9. Determine fat distribution within each cell for each view
10. Determine conformation/muscularity within each cell
11. Compute grade (reference to database/algorithm on raw data)
12. Compute fat/conformation interaction
13. Compute overall yield
14. Compute yield within each cell (primals)
15. Output data (stamp carcass/sort carcass)

Claims

1. A method of grading carcasses after slaughter comprising the steps of checking for the presence of a carcass in the field of view of a camera, exposing an image of the carcass from a plurality of different viewpoints, determining a plurality of dimensions of said carcass from said images and comparing said dimensions with stored values to determine the overall grading of said carcass.

2. A method of grading carcasses after slaughter as claimed in claim 1, further comprising the step of checking that the orientation of said carcass with respect to the camera is in accordance with a predetermined arrangement.

3. A method of grading carcasses after slaughter as claimed in claim 1 or claim 2 wherein at least one of said images is exposed from a lateral viewpoint.

4. A method of grading carcasses after slaughter as claimed in any one of the preceding claims wherein at least one of said images is exposed from a dorsal viewpoint.

5. A method of grading carcasses after slaughter as claimed in any one of the preceding claims wherein at least one of said images is exposed from a posterior/anterior viewpoint.

6. A method of grading carcasses after slaughter as claimed in any one of the preceding claims including the step of weighing the carcass.

7. A method of grading carcasses after slaughter as claimed in claim including the step of determining the sex of the from which the carcass is derived.

8. Apparatus for the grading carcasses after slaughter comprising a plurality of video cameras adapted to be positioned adjacent to a slaughter line to expose an image of a carcass on said slaughter line from a plurality of different viewpoints, signal processing means to derive from said images a plurality of parameters characteristic of said carcass, storage means to store a corresponding plurality of parameters derived from prior measurement of reference carcasses, comparator means to compare

said plurality of parameters with said corresponding plurality of parameters to derive a further parameter indicative of the grade of said carcass and indicator means to provide an indication of the magnitude of said further parameter.

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